CLASSIFICATION OF MARS PATHFINDER ROCK SURFACES USING QUANTITATIVE MORPHOLOGIC INDICES.

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Background: The Mars Pathfinder (MPF) landing site was originally predicted to contain a broad sampling of rock types varying in mineralogical, physical, mechanical and geochemical characteristics. Although rocks have been divided into several spectral categories based on Imager for Mars Pathfinder (IMP) visible/near-infrared spectra, it has not been fully determined which of these categories stem from intrinsic mineralogical differences between rocks or rock surfaces, and which result from factors such as physical or chemical weathering. This has made isolation of unique rock or rock surface mineralogies difficult.

Efforts in isolating and classifying spectral units among MPF rocks and soils have focused on refining our understanding of the spectra returned by the IMP, including the removal of smaller and smaller instrument calibration errors with respect to the radiometric calibration target (e.g.[1, 2]), modeling the spectral contribution of atmospheric dust [3-6], improving our understanding of the interactions between the various illumination factors (e.g.[7]), producing digital terrain models of the topographic variations on the surface and on rocks to correct for differences in spectral signature due to illumination angle (e.g.[8]), and attempting to spectrally isolate the effects of mantling dust [5, 6, 9]. These efforts have met with varying degrees of success, and the current state of understanding of each possible factor influencing spectral signature is such that many cannot currently be quantified to a sufficient level so they may be removed. The result of this fact is that many fundamental questions regarding information needed to reveal the present and past interactions between the rocks and rock surfaces and the Martian environment remain unanswered.

Approach and Method: It is possible to approach the issue of identifying the existence and distribution of distinct rock and rock surface types from a different angle. Morphology is another characteristic that is dependent upon the intrinsic properties and geologic and weathering history of rocks, among other things, and can be assessed quantitatively as a tool to diagnose various rock types in a scene. Correlated with spectral data, the use of both characteristics provides constraints on the number of rock and rock surface types at the MPF landing site. We have examined the morphology of rocks in two regions of the MPF landing site in terms of location, size and dimensions, sphericity and elongation, and have correlated this information with spectral data extracted from associated rock surfaces, with the goal of improving the likelihood of discerning between rock and rock surface types.

We use four highly diverse IMP images centered on Mini-Matterhorn and the Rock Garden because they are suited to demonstrate the wide morphologic variation of rocks at the site. A sampling of rocks was chosen at these locations that represented a range of shapes, textures and spectral signatures. In this initial analysis we focused upon the largest rocks that are situated in such a way as to allow easy viewing of most of the faces.

Rock location was derived by using previously established and published parameters [10, 11]. Because rock morphology and placement at the MPF site generally resemble the depositional plains left by terrestrial catastrophic floods [12], and have been interpreted as a plain composed of materials deposited by the Ares and Tiu catastrophic floods (e.g. [10, 13]), the shape of rocks at the MPF site have commonly been classified in terms of roundness, flatness/tabularity or angularity (e.g. [12, 14, 15]). Similarly, morphologic indices appropriate for rocks in this investigation include aspect ratio, apparent size, sphericity and elongation.

For comparison of morphology with spectral characteristics, the four IMP images were calibrated [1] and the most recently published sky model was applied [5]. Images were then registered to each other and stacked to create two hypercubes yielding information in the left (8 filters) and right (7 filters) camera eyes. Average spectra in 3x3 pixel boxes were extracted from each rock, for rock faces at a variety of surface normals. The general "color" of the rock surfaces in each scene was noted, and single spectra were taken to identify the detailed spectral signature of geologic features as well as any anomalous features. Identification of spectral features was made based upon these results. Spectral features such as the red/blue ratio, the slope between 800-1000 nm and the depth of any existing feature around 900-930 nm were measured. The two databases were then compared for trends that would indicate correlations between morphology and spectral signature. In order to highlight potential geologic variations, both individual wavelengths and ratios were examined.

Results. Two rock morphology categories (sphericity and elongation) were compared in terms of the red/blue ratio and the strength of the 600 nm "kink" (measured from the slope of the 670-530 nm continuum to the reflectance value at 600 nm). The results of these comparisons are shown in Figures 1 and 2. Figure 1 reveals no obvious trend between rock sphericity and spectral features that would indicate a correlation between this morphologic index and the red/blue ratio or the 600 nm kink. There are several possible explanations for this result: the association exists only for smaller rocks; this test case did not sample the rock faces, locations or sizes that would have illuminated this connection; or the correlation is below the level of the IMP images in their present state of calibration to detect it.

However, in terms of elongation, there is a possible correlation indicated. Though the rock surfaces with low or intermediate elongation appear to be unassociated with these spectral features, rocks displaying a high elongation index form a discrete cluster in Figure 2. This suggests a correlation between how elongated a rock is and the depth of its 600 nm "kink" — the more elongated the rock, the deeper the feature. This is consistent with the results obtained by [15], from which they hypothesized that spectral differences between rock morphologies arise because of differences in exposure age, with lesser development of dust coatings occurring on relatively recently exposed rocks. This preliminary result must necessarily be confirmed by subsequent measurements using refined calibration and sky models. In addition, spectra should be sampled from a variety of rock faces to rule out the possibility that the spectral signature is a result of greater levels of mantling dust on certain orientations, for example. However, the results of this assessment demonstrate the feasibility and utility of this method in providing constraints to models of rock geology, deposition and weathering history.

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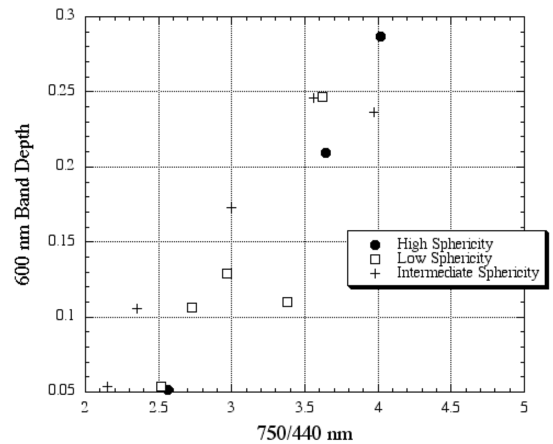

Figure 1. Sphericity as a function of 750/440 nm band ratio and 600 nm band depth.

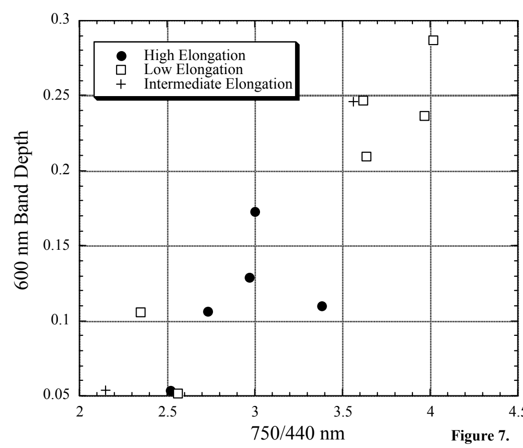

Figure 2. Rock elongation as a function of 750/440 nm band ratio and 600 nm band depth.